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# Two Types of Arctic Oscillation and Their Associated Rossby wave propagations

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In this study, the dynamical evolutions of two types of Arctic Oscillation (AO) on the intraseasonal time scale, the stratospheric (S) type and the tropospheric (T) type, have been investigated in terms of the transient eddy feedback forcing and the three-dimensional Rossby wave propagation. The S-Type (T-type) event is featured by the anomalous stratospheric polar vortex that is in phase (out-of-phase) with its tropospheric counterpart. About one third of all AO events are identified as the T-type event in both the positive and negative phase.

In the troposphere, the transient eddy feedback forcing is primarily responsible for the meridional seesaw structure of both the S- and T-type event, with additional contributions from the Rossby wave propagation. For the T-type of AO event, the formation and maintenance of stratospheric positive anomalies over the polar cap are associated with the upward propagation of Rossby wave packets originated from the near-tropopause altitude over northeastern Asia (Figure 1d, 1h, 1l). In addition to the upward propagation, the Rossby waves also propagate downward back into the troposphere over the North Atlantic, which contributes the formation of the height anomalies over the Iceland. But such upward/downward propagating features disappear for the S-type event, implying that the propagations of the planetary

waves might act as an important role in the formation of S-type AO event. Therefore, the underlying dynamical features that can differentiate itself from the S-type event lie in the vertical propagation of zonally confined Rossby waves.

Clearly shown in Figure 2, two vertical waveguides that extend throughout the troposphere and stratosphere exist over the North Asia/North Pacific region and over the North Atlantic. The former exhibits a somewhat westward-tilting structure with altitude. Therefore, once some circulation anomalies are developed and sustained in the upper troposphere/lower stratosphere over the Northeast Asia, the Rossby wave packets emanate from this region and propagate upward and eastward into the stratosphere. Before the peak pentad of the T-type event, the circulation anomalies over Northeast Asia are generally formed, and they tend to facilitate the Rossby wave packets to propagate upward, which contributes to the formation of anomalies centered over North America with the opposite sign. There is another vertical waveguide over the North Atlantic with relatively large  $k_s$  in the troposphere. Therefore, if some circulation anomalies persist on over North America in the stratosphere, the zonally confined Rossby waves might be continually refracted back into the troposphere along the local waveguide. Thus, the vertical waveguide over the North Atlantic could be

responsible for the locally downward injection of the Rossby wave packets that occurred in the T-type event.

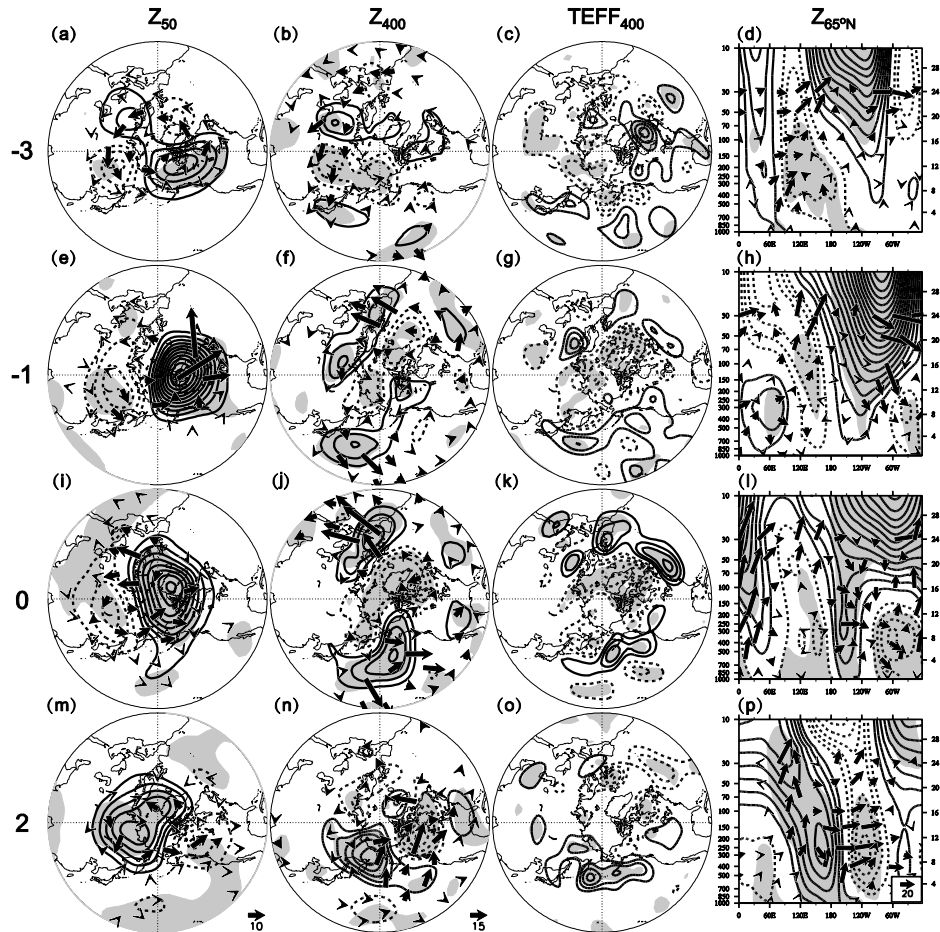
Therefore, the local waveguide structure well-explains the geophysical inclination of the vertical propagation of Rossby wave packets in the T-type event.

## References

- Ambaum M. H. P., B. J. Hoskins, and D. B. Stephenson, 2001: Arctic Oscillation or North Atlantic Oscillation? *J. Climate*, **14**, 3495–3507.
- Ambaum M. H. P., and B. J. Hoskins, 2002: The NAO Troposphere–Stratosphere Connection. *J. Climate*, **15**, 1969–1978.
- Baldwin M. P., and T. J. Dunkerton, 1999: Propagation of the Arctic Oscillation from the stratosphere to the troposphere. *J. Geophys. Res.*, **104**(D24), 30937–30946.
- Baldwin M. P., and T. J. Dunkerton, 2001: Stratospheric Harbingers of Anomalous Weather Regimes. *Science*, **294**(5542), doi: 10.1126/science.1063315.
- Baldwin M. P., and D. W. J. Thompson, 2009: A critical comparison of stratosphere–troposphere coupling indices. *Quart. J. Roy. Meteor. Soc.*, **135**(644), doi: 10.1002/qj.479.
- Bueh C., and H. Nakamura, 2007: Scandinavian Pattern and Its Climatic Impact. *Quart. J. Roy. Meteor. Soc.*, **133**(629), 2117–2131.
- Bueh C., N. Shi, and Z. Xie, 2011: Large-scale circulation anomalies associated with persistent low temperature over Southern China in January 2008. *Atmospheric Science Letters*, **12**(3), doi: 10.1002/asl.333.
- Chen W., and M. Takahashi, 2003: Interannual variations of stationary planetary wave activity in the northern winter troposphere and stratosphere and their relations to NAM and SST. *J. Geophys. Res.*, **108**, doi: 10.1029/2003JD003834.
- Cohen J., M. Barlow, P. J. Kushner, and K. Saito, 2007: Stratosphere–Troposphere Coupling and Links with Eurasian Land Surface Variability. *J. Climate*, **20**(21), 5335–5343.
- Christiansen B., 2001: Downward propagation of zonal mean zonal wind anomalies from the stratosphere to the troposphere: Model and reanalysis. *J. Geophys. Res.*, **106**(D21), doi: 10.1029/2000jd000214.
- Fletcher C. G., S. C. Hardiman, P. J. Kushner, and J. Cohen, 2009: The Dynamical Response to Snow Cover Perturbations in a Large Ensemble of Atmospheric GCM Integrations. *J. Climate*, **22**(5), 1208–1222.
- Fletcher C. G., and P. J. Kushner, 2011: The role of linear interference in the annular mode response to tropical SST forcing. *J. Climate*, **24**, 778–794.
- Garfinkel C., D. Hartmann, and F. Sassi, 2010: Tropospheric precursors of anomalous Northern Hemisphere stratospheric polar vortices. *J. Climate*, **23**, 3282–3299.
- Gong G., and D. Entekhabi, 2003: Modeled Northern Hemisphere Winter Climate Response to Realistic Siberian Snow Anomalies. *J. Climate*, **16**, 3917–3931.
- Hartley D. E., J. T. Villarin, R. X. Black, and C. A. Davis, 1998: A new perspective on the dynamical link between the stratosphere and troposphere. *Nature*, **391**, 471–473.
- Hinssen Y., A. v. Delden, and T. O. a. W. d. Geus, 2010: Stratospheric impact on tropospheric winds deduced from potential vorticity inversion in relation to the Arctic Oscillation. *Quart. J. Roy. Meteor. Soc.*, **136**, 20–29.
- Holopainen E., and C. Fortelius, 1987: High-Frequency Transient Eddies and Blocking. *J. Atmos. Sci.*, **44**(12), 1632–1645.
- Kanamitsu M., W. Ebisuzaki, J. Woollen, S.-K. Yang, J. J. Hnilo, M. Fiorino, and G. L. Potter, 2002: NCEP–DOE AMIP-II Reanalysis (R-2). *Bull. Amer. Meteor. Soc.*, **83**(11), 1631–1643.
- Karoly D. J., and B. J. Hoskins, 1982: Three dimensional propagation of planetary waves. *J. Meteor. Soc. Japan*, **60**, 109–123.
- Kodera K., K. Yamazaki, M. Chiba, and K. Shibata, 1990: Downward propagation of upper stratospheric mean zonal wind perturbation to the troposphere. *Geophys. Res. Lett.*, **17**(9), doi: 10.1029/GL017i009p01263.
- Kodera K., and Y. Kuroda, 2000: Tropospheric and Stratospheric Aspects of the Arctic Oscillation. *Geophys. Res. Lett.*, **27**, 3349–3352.
- Kuroda Y., 2002: Relationship between the Polar-Night Jet Oscillation and the Annular Mode. *Geophys. Res. Lett.*, **29**(8), doi: 10.1029/2001gl013933.

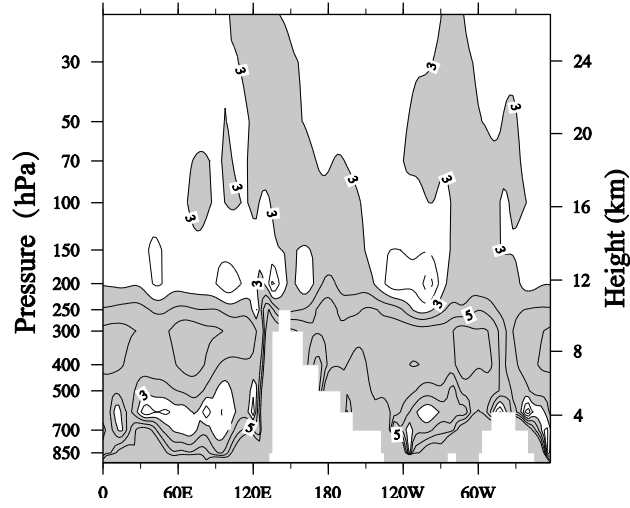
- Lau N.-C., and E. O. Holopainen, 1984: Transient Eddy Forcing of the Time-Mean Flow as Identified by Geopotential Tendencies. *J. Atmos. Sci.*, **41**(3), 313–328.
- Lau N.-C., and M. J. Nath, 1991: Variability of the baroclinic and barotropic transient eddy forcing associated with monthly changes in the midlatitude storm tracks. *J. Atmos. Sci.*, **48**, 2589–2613.
- Li S., M. P. Hoerling, S. Peng, and K. M. Weickmann, 2006: The Annular Response to Tropical Pacific SST Forcing. *J. Climate*, **19**(9), 1802–1819.
- Li S., X. Chen, J. Perlwitz, and M. Hoerling, 2010: Opposite annular responses of the Northern and Southern Hemisphere to Indian Ocean warming. *J. Climate*, **23**, 3720–3738.
- Limpasuvan V., and D. L. Hartmann, 1999: Eddies and the annular modes of climate variability. *Geophys. Res. Lett.*, **26**(20), doi: 10.1029/1999gl010478.
- Limpasuvan V., and D. L. Hartmann, 2000: Wave-Maintained Annular Modes of Climate Variability. *J. Climate*, **13**(24), doi: 10.1175/1520-0442(2000)013<4414:WMAMOC>2.0.CO;2.
- Lorenz D. J., and D. L. Hartmann, 2003: Eddy–Zonal Flow Feedback in the Northern Hemisphere Winter. *J. Climate*, **16**, 1212–1227.
- Lu J., R. J. Greatbatch, and K. A. Peterson, 2004: Trend in Northern Hemisphere Winter Atmospheric Circulation during the Last Half of the Twentieth Century. *J. Climate*, **17**, 3745–3760.
- Matsuno T., 1971: A Dynamical Model of the Stratospheric Sudden Warming. *J. Atmos. Sci.*, **28**(8), 1479–1494.
- McDaniel B. A., and R. X. Black, 2005: Intraseasonal Dynamical Evolution of the Northern Annular Mode. *J. Climate*, **18**(18), doi:10.1175/JCLI3467.1.
- Nakamura H., and J. M. Wallace, 1993: Synoptic behavior of baroclinic eddies during the blocking onset. *Mon. Wea. Rev.*, **121**, 1892–1903.
- Nakamura H., and M. Honda, 2002: Interannual Seesaw between the Aleutian and Icelandic Lows Part III: Its Influence upon the Stratospheric Variability. *J. Meteor. Soc. Japan*, **80**(4B), 1051–1067.
- Nishii K., and H. Nakamura, 2004: Lower-stratospheric Rossby wave trains in the southern hemisphere: A case-study for late winter of 1997. *Quart. J. Roy. Meteor. Soc.*, **130**(596), 325–345.
- Nishii K., and H. Nakamura, 2005: Upward and downward injection of Rossby wave activity across the tropopause: A new aspect of the troposphere–stratosphere dynamical linkage. *Quart. J. Roy. Meteor. Soc.*, **131**, 545–564.
- Nishii K., H. Nakamura, and T. Miyasaka, 2009: Modulations in the planetary wave field induced by upward-propagating Rossby wave packets prior to stratospheric sudden warming events: A case-study. *Quart. J. Roy. Meteor. Soc.*, **135**, 39–52.
- Nishii K., H. Nakamura, and Y. J. Orsolini, 2010: Cooling of the wintertime Arctic stratosphere induced by the western Pacific teleconnection pattern. *Geophys. Res. Lett.*, **37**(13), doi: 10.1029/2010gl043551.
- Nishii K., H. Nakamura, and Y. J. Orsolini, 2011: Geographical dependence observed in blocking high influence on the stratospheric variability through enhancement and suppression of upward planetary-wave propagation. *J. Climate*, doi: 10.1175/jcli-d-10-05021.1.
- Perlwitz J., and N. Harnik, 2003: Observational Evidence of a Stratospheric Influence on the Troposphere by Planetary Wave Reflection. *J. Climate*, **16**(18), 3011–3026.
- Plumb R. A., 1985: On the Three-Dimensional Propagation of Stationary Waves. *J. Atmos. Sci.*, **42**(3), 217–229.
- Shi N., and C. Bueh, 2011: Two Types of Arctic Oscillation and Their Associated Dynamic Features. *Atmospheric and Oceanic Science Letters*, **4**(5), 287–292.
- Smith K. L., C. G. Fletcher, and P. J. Kushner, 2010: The Role of Linear Interference in the Annular Mode Response to Extratropical Surface Forcing. *J. Climate*, **23**(22), 6036–6050.
- Takaya K., and H. Nakamura, 2001: A formulation of a phase-Independent wave-activity flux for stationary and migratory quasigeostrophic eddies on a zonally varying basic flow. *J. Atmos. Sci.*, **58**(6), 608–627.
- Thompson D. W. J., and J. M. Wallace, 1998: The Arctic Oscillation signature in the wintertime geopotential height and temperature fields.

- Geophys. Res. Lett.*, **25**, 1297–1300.
- Thompson D. W. J., and J. M. Wallace, 2000: Annular Modes in the Extratropical Circulation. Part I: Month-to-Month Variability. *J. Climate*, **13**(5), doi:10.1175/1520-0442(2000)013<1000:AMITEC>2.0.CO;2.
- Thompson D. W. J., J. J. Kennedy, J. M. Wallace, and P. D. Jones, 2008: A large discontinuity in the mid-twentieth century in observed global-mean surface temperature. *Nature*, **453**(7195), doi: 10.1038/nature06982.
- Vallis G. K., E. P. Gerber, P. J. Kushner, and B. A. Cash, 2004: A mechanism and simple dynamical model of the North Atlantic Oscillation and annular modes. *J. Atmos. Sci.*, **61**(3), 264–280.
- Wallace J. M., and D. S. Gutzler, 1981: Teleconnections in the geopotential height field during the Northern Hemisphere winter. *Mon. Wea. Rev.*, **109**, 784–812.
- Wang H., J. Sun, and J. Su, 2008: The northern annular mode: More zonal symmetric than the southern annular mode. *Chinese Science Bulletin*, **53**(11), doi: 10.1007/s11434-008-0114-y.
- Zhao N., X. Shen, Y. Li, and Y. Ding, 2009: Modal aspects of the Northern Hemisphere annular mode as identified from the results of a GCM run. *Theoretical and Applied Climatology*, **101**, doi: 10.1007/s00704-009-0210-1.
- Zhu Y., Wang H (2008) The Arctic and Antarctic oscillations in the IPCC AR4 coupled models. *Acta Meteorologica Sinica* **66**: 993–1004. (in Chinese)



**Figure 1** Composite time evolution of anomalous  $Z_{50}$ ,  $Z_{400}$ , transient eddy feedback forcing at 400 hPa ( $TEFF_{400}$ ) and zonal-height section of height anomalies at  $65^{\circ}\text{N}$  ( $Z_{65^{\circ}\text{N}}$ ) associated with

the 10 T-type AO events. Contour intervals are 40 m, 35 m, 4 m/day and 40 m for  $Z_{50}$ ,  $Z_{400}$ ,  $TEFF_{400}$  and the cross-section, respectively. Arrows ( $m^2 s^{-2}$ ) are wave activity flux based on the composite anomalies and they have been normalized with pressure. Shading marks the region of 90% confidence level.



**Figure 2.** Meridional section of total stationary Rossby wavenumber,  $k_s$ , at  $65^\circ N$ , based on the climatological-mean state in the expanded winter. The  $k_s$  has been represented as the “equivalent zonal wavenumber.” Only the  $k_s$  exceeding 3 are shaded.